REMARKS

Claims 19, 61, and 88 are currently pending. Claims 66-87, and 89-93 have been canceled without prejudice or disclaimer. Claim 19 has been amended with the subject matter of canceled claim 66. It is respectfully submitted that no new matter has been added, no new issues have been raised, and no search and consideration is further required beyond that which would occur had no amendment been submitted as the claimed subject matter was presented in the previous response. Entry of this amendment is therefore respectfully submitted.

35 U.S.C. 103(a) Rejections

The Patent Office rejected claims 19, 61, 66, 82, and 88 under 35 U.S.C. 103(a) as being unpatentable over Li, U.S. Published Patent Application No. 2004/0192021.

The Patent Office has made an obviousness rejection of the claims, but has not provided a Graham v. Deere analysis. Applicant requests such analysis.

Claim 19 recites as follows:

> A diffusion barrier comprising a plurality of stacked amorphous sub-layers, each sub-layer having a thickness of about 0.4 to about 4.5 nanometers (nm), wherein **the plurality of stacked amorphous sub-layers** are arranged collectively to inhibit diffusion of a chemical species through the diffusion barrier, and where the plurality of stacked amorphous sub-layers are between three and ten in number, wherein the stacked amorphous sub-layers are of alternating composition, where an amorphous sub-layer of tantalum (Ta) alternates with an amorphous sub-layer of copper (Cu), wherein the amorphous sub-layers in the diffusion barrier are mutually adhesive, wherein the diffusion barrier is a circuit interconnect.

Li discloses, in paragraph 0029, a diffusion barrier. Li discloses in paragraph 0029 as follows:

> [0029] In the first step of the process, the diffusion barrier layer 114, 214 is deposited by PEALD or by ALD over a dielectric layer of an integrated circuit. **The diffusion barrier layer 114, 214 is made of refractory metal and preferably contains a nitride of the refractory metal or a metal carbide.** Suitable

> refractory metals are for example Ta, Ti, Zr, Hf, W, Mo, Co, Cr, Pd, and Nb. Suitable metal nitrides include, for example, tantalum nitride, titanium nitride, tungsten nitride, and hafnium nitride. **The refractory metal is more preferably tungsten (W), tantalum (Ta) or titanium (Ti). The diffusion barrier layer may be, for example, a thin film that contains W, WN and WC (W/WN_xC_y)**, or a **nanolaminate**, such as a sandwich of Ta and **TaN (Ta/TaN)**, or Ti and TiN (Ti/TiN). **The thickness of the barrier layer is preferably between about 0.3 nm-5 nm.**

Li discloses that the diffusion barrier layer may be a tantalum/ tantalum nitride or perhaps just tantalum, in an embodiment, where the entire thickness of the barrier layer is preferably between 0.3 nanometers and 5 nanometers.

Applicant notes that the claimed invention also recites "the plurality of stacked amorphous sub-layers are between three and ten in number."

Li also discloses a dual layer structure of the single layer diffusion barrier layer and a graded metal alloy layer. Figure 1 shows a trench that is first covered by a diffusion barrier layer 114 and then covered by a copper seed 116 for adhesion and is then filled with copper metal bulk fill 118 (see paragraph 0023). Figure 2 shows a partial transistor structure having a diffusion barrier layer 214 formed on a gate dielectric 208, a metal alloy layer 216 formed on the diffusion barrier layer 214, and a gate metal 218 formed on the metal alloy layer 216.

Paragraphs 0030 and 0031 of Li describe the graded metal alloy layer 116, 216, as follows:

> [0030] In a subsequent step, a layer of a graded metal alloy 116, 216 is deposited over the diffusion barrier layer by an ALD process, preferably by PEALD. **The layer contains at least two metals and preferably comprises one of the metals used in the diffusion barrier layer.** In the preferred embodiment the layer comprises one of the metals used. in the diffusion barrier and copper. For example, when the diffusion barrier layer contains tungsten, the alloy layer preferably contains an alloy of tungsten and copper. **When the diffusion barrier layer contains tantalum, the metal alloy layer is preferably made of tantalum and copper. The thickness of the metal alloy layer is preferably between about 10 .ANG. and 25 .ANG.**. Inter-mixing of different metals in the diffusion barrier and the alloy layer is possible as well.

> [0031] In the first embodiment, **the graded composition of the metal alloy layer 116, 216 is realized by depositing several very thin and alternating sublayers of two metals**. Their thickness is varied to provide a graded composition of the metals in the alloy layer 116, 216: The metal alloy layer acts as a **barrier-adhesion-seed layer as such or together with an ALD barrier layer**. In the latter case, the metal alloy layer is preferably deposited over the ALD barrier layer.

Li discloses that the graded metal alloy layer is preferably 1.0 to 2.5 nanometers thick. Li discloses that the graded metal alloy "**layer contains at least two metals and preferably comprises one of the metals used in the diffusion barrier layer.**" In the preferred embodiment of Li, the diffusion layer may be made of metal A and the graded metal alloy layer may be made of an alloy that includes metal A.

In paragraph 0029, Li discloses "**The diffusion barrier layer may be, for example, a thin film that contains W, WN and WC (W/WN_xC_y)**, or a **nanolaminate**, such as a sandwich of Ta and **TaN (Ta/TaN)**, or Ti and TiN (Ti/TiN)." In paragraph 0029, Li does not state that the diffusion barrier layer may be tantalum or copper. Li does allow for a nanolaminate of Ta/ TaN to serve as the diffusion barrier layer. In Li, **the thickness of the barrier layer is preferably between about 0.3 nm-5 nm.**

Paragraph 0030 of Li discloses "**when the diffusion barrier layer contains tantalum, the metal alloy layer is preferably made of tantalum and copper.**" If a nanolaminate of Ta/ TaN comprised the diffusion barrier layer, then the metal alloy layer would preferably be made of tantalum and copper. Since the diffusion barrier layer may be 0.3 to 5.0 nm thick and may consist of a nanolaminate of tantalum and tantalum nitride and since the graded metal alloy layer may be formed of tantalum and copper in an alternating manner as described in paragraphs 0033 to 0035, a structure of a nanolaminate of tantalum and tantalum nitride followed by alternating layers of tantalum and copper may be formed.

In paragraphs 0041 through 0079, three examples are provided of processing to produce a barrier layer, an adhesion layer, and a seed layer. The first and third examples disclose the use of tungsten, not tantalum. In paragraph 0057, Li discloses 10 cycles PEALD TaN and 10 cycles PEALD Ta to produce a barrier layer of Ta/TaN about 2.5

nanometers thick. Then, in paragraph 0063, Li discloses 10 times of 1 cycle PEALD Cu and 1 cycle PEALD Ta to produce a nanolaminate layer of about 5 nanometers thick. Finally, in paragraph 0066, Li discloses 50 deposition cycles of PEALD to produce a 1 nanometer thick copper layer. The overall combined thickness of the barrier-adhesion-seed layer is about 8.5 nanometers.

Li does not positively disclose a "**plurality of stacked amorphous sub-layers**." In contrast to Applicant's disclosed invention, Li, which uses only ALD or PEALD, is limited by the presence of unwanted chemical contaminants, such as Cl. Additionally, the Patent Office has not provided a Graham v Deere analysis. From MPEP 2141:

> **II. The Basic Factual Inquiries of Graham v. John Deere Co.**
>
> An invention that would have been obvious to a person of ordinary skill at the time of the invention is not patentable. See 35 U.S.C. **103(a)**. As reiterated by the Supreme Court in *KSR*, the framework for the objective analysis for determining obviousness under 35 U.S.C. **103** is stated in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966). Obviousness is a question of law based on underlying factual inquiries. The factual inquiries enunciated by the Court are as follows:
>
> (A) Ascertaining the differences between the claimed invention and the prior art; and
>
> (B) Ascertaining the differences between the claimed invention and the prior art; and
>
> (C) Resolving the level of ordinary skill in the pertinent art.

Without a Graham v Deere type analysis, the obviousness rejection is incomplete. Applicant requests that a complete analysis of claim 19 in light of the prior art be provided or an indication of the allowability of claim 19. Furthermore, the Patent Office has not provided where in the prior art, by column and line number or by part number and drawing figure, the claimed subject matter is allegedly taught. Applicant requests that the Patent Office a sufficiently detailed analysis of the prior art in rejecting the claimed invention.

The Patent Office is respectfully requested to reconsider and remove the rejections of claim 19 under U.S.C. 103(a) based on Li. Allowance of currently pending claim 19 is earnestly solicited.

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